The Aquatic Plant Community in Wolf Lake, Adams County 2005

Executive Summary

Wolf Lake is an oligotrophic lake with very good water quality and excellent water clarity. Nutrients and algae have increased since 1997. Filamentous algae is common in Wolf Lake, abundant in the 5-10ft depth zone.

The aquatic plant community colonized approximately half of Wolf Lake, 100% of the littoral zone to a maximum rooting depth of 17.5 feet. The 0-1.5ft depth zone supported the most abundant aquatic plant growth. The Wolf Lake aquatic plant community is characterized by high quality and excellent species diversity. The plant community has a below average sensitivity to disturbance and is closer to an undisturbed condition than the average lake in the state.

Chara spp. and *Elodea canadensis* were the co-dominant species. *Najas guadalupensis* was sub-dominant. The most common species (except Eurasian watermilfoil) were found distributed throughout the lake. Eurasian watermilfoil was a commonly occurring species, but occurred at below average densities and was abundant only at depths greater than 10 feet.

A healthy aquatic plant community plays a vital role within the lake community. This is due to the role plants play in improving water quality, providing valuable habitat resources for fish and wildlife, resisting invasions of non-native species and checking excessive growth of the most tolerant species.

Management Recommendations

1) All lake residents should practice best management on their lake properties, including keeping septic systems cleaned and in proper condition, eliminating the use of lawn fertilizers, cleaning up pet wastes and not composting near the water.
2) Residents should continue involvement in the Volunteer Lake Monitoring Program.
3) Adams County should designate sensitive areas within Wolf Lake.
4) Lake residents should protect and restore natural shoreline around Wolf Lake. The lower frequency and density of the most sensitive plant species in the disturbed shoreline areas is evidence that shore disturbance is impacting the aquatic plant community of the lake. Disturbed shoreline sites support an aquatic plant community that has been less able to resist invasions of exotic species and shows impacts from nutrient enrichment.
5) All lake users should protect the aquatic plant community in Wolf Lake.
6) Lake Association should maintain exotic species signs at the boat landings and contact DNR if the signs are missing or damaged.

7) Lake Association should continue monitoring and control of Eurasian watermilfoil maintain the most effective methods and modify if necessary. Early-season treatments with a specific chemical should be continued as long as it remains effective. The Lake Association should investigate ways to increase treatment effectiveness in the deeper water. Residents may need to hand pull scattered plants.
8) Lake Association should contract with a University or the County to have a milfoil weevil survey conducted.

I. INTRODUCTION

A study of the aquatic macrophytes (plants) in Wolf Lake was conducted during July 2005 by Water Resources staff of the West Central Region - Department of Natural Resources (DNR) and Adams County Land and Water Conservation. An assessment of the aquatic plant community was conducted in 1948 by state fishery staff. Quantitative surveys were conducted in May 2002 and May 2004 by a private consultant to assess Eurasian watermilfoil colonization using different transect placements. However, 2005 was the first quantitative vegetation study of Wolf Lake by the DNR in the summer.

A study of the diversity, density, and distribution of aquatic plants is an essential component of understanding a lake ecosystem due to the important ecological role of aquatic vegetation in the lake and the ability of the vegetation to characterize the water quality (Dennison et al. 1993).

Ecological Role: All other life in the lake depends on the plant life - the beginning of the food chain. Aquatic plants and algae provide food and oxygen for fish, wildlife, and the invertebrates that in turn provide food for other organisms. Plants provide habitat, improve water quality, protect shorelines and lake bottoms, add to the aesthetic quality of the lake and impact recreation.

Characterize Water Quality: Aquatic plants serve as indicators of water quality because of their sensitivity to water quality parameters, such as water clarity and nutrient levels (Dennison et. al. 1993).

The present study will provide information that is important for effective management of the lake, including fish habitat improvement, protection of sensitive habitat, aquatic plant management and water quality protection. The baseline data that it provides will be compared to past and future aquatic plant inventories and offer insight into changes occurring in the lake.

Background and History: Wolf Lake is a 49-acre seepage lake in southeast Adams County, Wisconsin. Wolf Lake has a maximum depth of 47 feet. The Wolf Lake watershed drains approximately 150 acres, which is a 3:1 watershed to lake surface ratio. With such a relatively small watershed, it is likely that shoreline properties contribute more nutrient runoff than the watershed itself.

Eurasian watermilfoil was introduced into Wolf Lake before 2000. By 2001, it had colonized large portions of the watershed in areas up to 20 feet deep (Cason and Roost 2004). Limited herbicide treatments for controlling the Eurasian watermilfoil were started in 2001 (Table 1). Since lakewide Eurasian watermilfoil treatments were started in 2002, the acreage of treatment has generally declined (Table 1). This suggests that the treatments as currently conducted are successful. Monitoring the acreage of milfoil colonization should be continued to ensure that the current management is successful.

Table 1. Herbicide Treatments for Eurasian Watermilfoil

	Spring/Summer Treatment		Fall Treatment	
	Acres	Navigate (lbs)	Acres	Navigate (lbs)
2001*	0.2	30	0.9	83
2002	8.4	839		
2003	9.5	950		
2004	2.0	200		
2005	5.0	500	0.7	140
Totals		2519		223

* Treatment conducted by individual landowners using Aquacide, a more readily available formulation of 2, 4-D.

II.METHODS

Field Methods

The study design was based on the rake-sampling method developed by Jessen and Lound (1962), using stratified random placement of the transect lines. The shoreline was divided into 14 equal segments and a transect, perpendicular to the shoreline, was randomly placed within each segment (Appendix IV), using a random numbers table.

One sampling site was randomly located in each depth zone (0-1.5ft, 1.5-5ft, 5-10ft and 10-20ft) along each transect. Using a long-handled, steel, thatching rake, four rake samples were taken at each sampling site, one from each quarter of a 6-foot diameter quadrat. The aquatic plant species that were present on each rake sample were recorded. Each species was given a density rating (0-5), the number of rake samples on which it was present at each sampling site.

a rating of 1 indicates that a species was present on one rake sample at that site
a rating of 2 indicates that a species was present on two rake samples at that site
a rating of 3 indicates that it was present on three rake samples
a rating of 4 indicates that it was present on all four rake samples

a rating of 5 indicates that a species was abundantly present on all 4 rake samples at that site.

Visual inspection and periodic samples were taken between transect lines to record the presence of any species that did not occur at the sampling sites. Specimens of all plant species present were collected and saved in a cooler for later preparation of voucher specimens. Nomenclature was according to Gleason and Cronquist (1991).

The type of shoreline cover was recorded at each transect. A section of shoreline 50 feet on each side of the transect intercept with the shore and 30 feet deep was evaluated. The percent cover of each land use category within this 100' x 30' rectangle was visually estimated and verified by a second researcher.

Data Analysis

The percent frequency of each species was calculated (number of sampling sites at which it occurred/total number of sampling sites) (Appendix I). Relative frequency was calculated (number of occurrences of a species/sum of all species occurrences) (Appendix I). The mean density was calculated for each species (sum of a species' density ratings/number of sampling sites) (Appendix II). Relative density was calculated (sum of a species density/sum of all plant densities). "Mean density where present" was calculated for each species (sum of a species' density ratings/number of sampling sites at which the species occurred) (Appendix II). The relative frequency and relative density of each species were summed to obtain a dominance value for each species (Appendix III). Species diversity was measured by Simpson's Diversity Index (Appendix I).

The Aquatic Macrophyte Community Index (AMCI) developed by Nichols (2000) was applied to Wolf Lake. Measures for each of seven categories that characterize a plant community are converted to values between 0 and 10 and summed to measure the quality of the plant community.

The Average Coefficient of Conservatism and Floristic Quality Index were calculated, as outlined by Nichols (1998), to measure disturbance in the plant community. A coefficient of conservatism is an assigned value, 0-10, the probability that a species will occur in an undisturbed habitat. The Average Coefficient of Conservatism is the mean of the coefficients for all species found in the lake. The Floristic Quality Index is calculated from the Coefficient of Conservatism (Nichols 1998) and is a measure of a plant community's closeness to an undisturbed condition.

III. RESULTS

PHYSICAL DATA

Many physical parameters impact the aquatic plant community. Water quality (nutrients, algae, water clarity, pH and water hardness) influence the plant community as the plant community can in turn modify these parameters. Lake morphology, sediment composition and shoreline use also impact the aquatic plant community.

WATER QUALITY - The trophic state of a lake is a classification of its water quality. Phosphorus concentration, chlorophyll concentration and water clarity data are collected and combined to determine the trophic state.

Eutrophic lakes are high in nutrients and support a large biomass.
Oligotrophic lakes are low in nutrients and support limited plant growth and smaller populations of fish.
Mesotrophic lakes have intermediate levels of nutrients and biomass.

Volunteer lake monitors in the Self-Help Volunteer Lake Monitoring program have been sampling Wolf Lake since 1990. Kathryn Houlet monitored Wolf Lake water clarity 1990-1992; Norman Erickson has been monitoring Wolf Lake since 1992 (water clarity since 1992 and chemistry monitoring since 1997). The volunteer lake data is valuable in that it is gathered for more consecutive years and more frequently during the year than data from other agencies.

Nutrients
Phosphorus is a limiting nutrient in many Wisconsin lakes and is measured as an indication of nutrient enrichment in a lake. Increases in phosphorus in a lake can feed algae blooms and, occasionally, excess plant growth.

2004 Mean Summer Phosphorus concentration in Wolf Lake was 12.3 ug/l

This concentration of phosphorus in Wolf Lake is indicative of a mesotrophic lake (Table 2).

Table 2. Trophic Status

	Quality Index	Phosphorus ug/l	Chlorophyll ug/l	Secchi Disc ft.
Oligotrophic	Excellent	<1	<1	**> 19**
	Very Good	1-10	**1-5**	8-19
Mesotrophic	Good	**10-30**	5-10	6-8
	Fair	30-50	10-15	5-6
Eutrophic	Poor	50-150	15-30	3-4
Wolf Lake 2004 Mean Summer	Very Good	12.3	1.7	20.7

After Lillie & Mason (1983) & Shaw et. al. (1993)

Algae

Chlorophyll concentrations provide a measure of the amount of algae in lake water. Algae are natural and essential in lakes, but high algae populations can increase turbidity and reduce the light available for plant growth.

2004 Mean summer chlorophyll concentration in Wolf Lake was 1.7 ug/l.

The chlorophyll concentration in Wolf Lake was in the oligotrophic range (Table 2).

Filamentous algae occurred at 31% of all sample sites. In 2005, filamentous algae occurred at:

36% of the sites in the 0-1.5ft depth zone
28% of the sites in the 1.5-5ft depth zone
42% of the sites in the 5-10ft depth zone
17% of the sites in the 10-20ft depth zone

Variations in the concentration of phosphorus and chlorophyll concentrations are caused by variations in weather and rain events from year to year. As expected, the chlorophyll variations from year to year follow the variations in phosphorus as algae use available nutrients to multiply. Based on the volunteer chemistry data, chlorophyll has increased slightly since 1997 and phosphorus has increased even more (Figure 1).

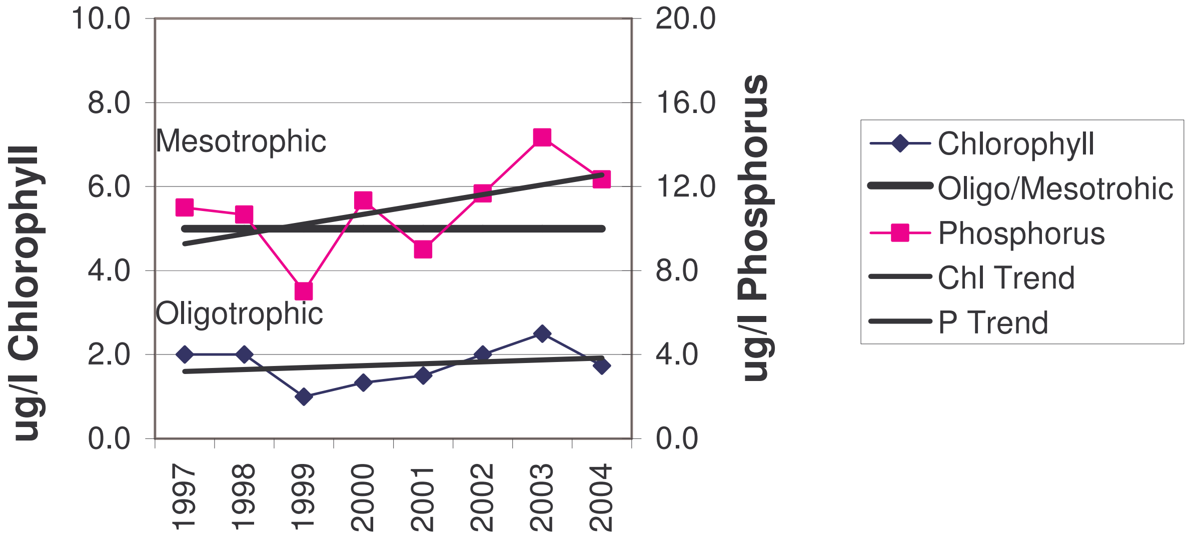


Figure 1. Mean summer phosphorus and chlorophyll in Wolf Lake, 1997-2004.

Water Clarity

Water clarity is a critical factor for aquatic plants. When plants receive less than 1 - 2% of the surface illumination, they can not survive. Water clarity is reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that color the water. Water clarity is measured with a Secchi disc that shows the combined effect of turbidity and color

2004 Mean Summer Secchi Disc clarity in Wolf Lake was 20.7 ft.

Water clarity indicates (Table 2) that Wolf Lake was an oligotrophic lake with excellent water clarity.

The combination of phosphorus concentration, chlorophyll concentration and water clarity indicates that Wolf Lake is an oligotrophic lake with very good water quality. This trophic state should favor sparse plant growth and infrequent summer algae blooms.

Volunteer monitoring data indicate that water clarity in Wolf Lake varies from year to year (Figure 2). The lowest mean summer water clarity recorded was in 2002-2003 and the best clarity was recorded in 2004.

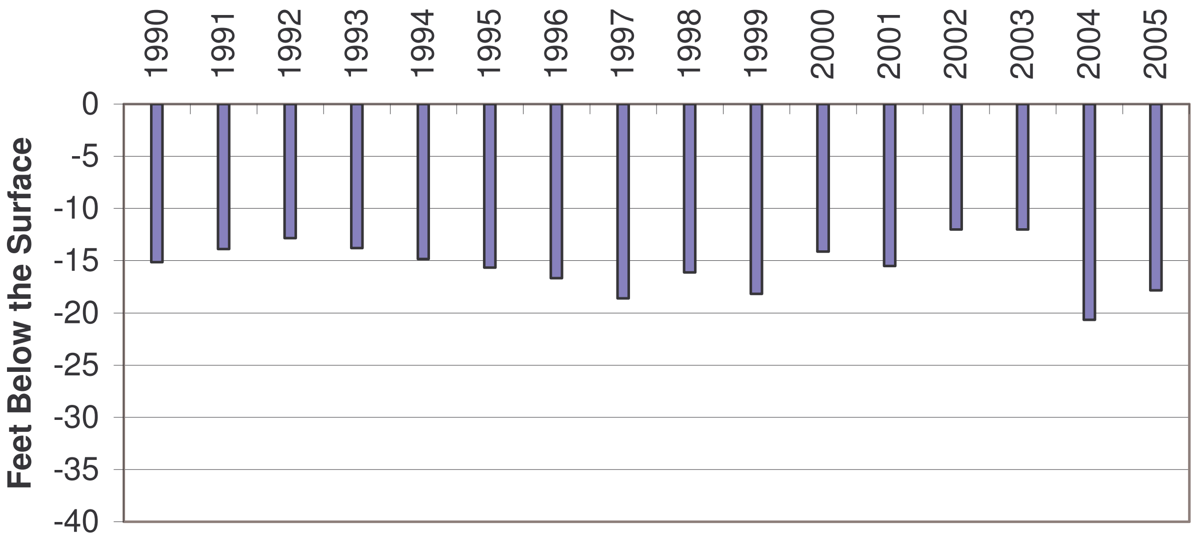


Figure 2. Change in summer mean water clarity in Wolf Lake, 1990-2004

Because the volunteer data has been collected over several years and over the entire ice-off season, changes in clarity during the growing season can be seen. Data collected at the same time during the year was averaged. Water clarity in Wolf Lake is greater early in the growing season until clarity decreases in the summer as the water warms (Figure 3).

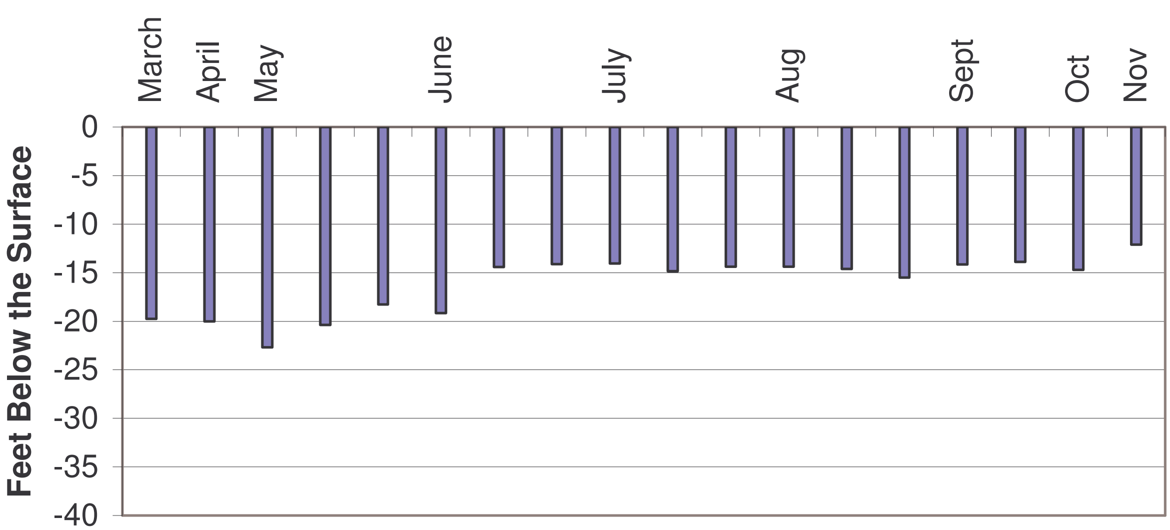


Figure 3. Change in water clarity during in the growing season in Wolf Lake, 1990-2004.

HARDNESS-- The hardness or mineral content of lake water also influences aquatic plant growth. Lakes with hardness values of 61-120mg/l $CaCO_3$ are considered moderately hard water lakes. Hard water lakes tend to support more plant growth than soft water lakes.

LAKE MORPHOMETRY - The morphometry of a lake is an important factor in determining the distribution of aquatic plants. Duarte and Kalff (1986) found that the slope of the littoral zone could explain 72% of the observed variability in the growth of submerged plants. Gentle slopes support more plant growth than steep slopes (Engel 1985).

Wolf Lake has an oval basin with a moderately-sloped littoral zone over most of the lake and a gradually sloped littoral zone in the southeast corner (Appendix IV). Gradual slopes provide a more stable rooting base and broader area of shallow water that would favor plant growth.

SEDIMENT COMPOSITION – The dominant sediment in Wolf Lake was marl, especially at depths greater than 10ft (Table 3). A hard, high-density sediment, sand, was common in the shallow zone; mixed with silt, it was dominant in the shallow zone. Silt/marl mixtures were common at depths of 1.5-10 feet (Figure 4).

Table 3. Sediment Composition: Wolf Lake, 2005

Sediment Type		0-1.5' Depth	1.5-5' Depth	5-10' Depth	10-20' Depth	Percent of all Sample Sites
Soft Sediments	Marl		21%	33%	83%	33%
	Silt/Marl		36%	50%	17%	25%
	Silt	14%	36%	17%		17%
Mixed Sediments	Sand/Silt	50%	7%			15%
Hard Sediments	Sand	36%				10%

INFLUENCE OF SEDIMENT - Some plants depend on the sediment in which they are rooted for their nutrients. The richness or sterility and texture of the sediment will determine the type and abundance of plant species that can survive in a location. The availability of mineral nutrients for growth is highest in sediments of intermediate density, such as silt, so these sediments are considered most favorable for plant growth (Barko and Smart 1986).

Marl was the overall dominant sediment found in Wolf Lake; sand and sand/silt mixtures were common in the shallow zone. All sites were vegetated in Wolf Lake, irregardless of the sediment type (Table 3). It appears that sediment is not a major factor determining plant distribution in Wolf Lake.

SHORELINE LAND USE – Land use can strongly impact the aquatic plant community and therefore the entire aquatic community. Land use can directly impact the plant community through increased erosion and sedimentation and increased run-off of nutrients, fertilizers and toxics applied to the land. These impacts occur in both rural and residential settings.

Native herbaceous plant cover was the most frequently encountered shoreline cover at the transects and wooded cover had the highest mean coverage. Shrub cover had a high occurrence also (Table 4).

Cultivated lawn and hard structures also had high occurrences and lawn had a high coverage (Table 4).

Table 4. Shoreline Land Use - Wolf Lake, 2005

Cover Type		Frequency of Occurrences at Transects	Mean % Coverage
Natural Shoreline	Native Herbaceous	86%	21%
	Wooded	78%	32%
	Shrub	64%	10%
	Bare Sand	7%	1%
	Rock	7%	1%
Total Natural			65%
Disturbed Shoreline	Cultivated Lawn	57%	30%
	Hard Structures	36%	4%
	Rip-Rap	7%	1%
Total Disturbed			35%

Some type of natural shoreline (wooded, shrub, native herbaceous, sand) was found at all of the sites, having a mean coverage of 65%.

Some type of disturbed shoreline (cultivated lawn, hard structures and rip-rap) was found at 71% of the sites and had a mean coverage of 35%.

MACROPHYTE DATA

SPECIES PRESENT

Of the 32 species found in Wolf Lake, 6 were emergent species, 2 were floating-leaf species and 24 were submergent species (Table 5). No threatened or endangered species were found. Three exotic invasive species was found: *Myriophyllum spicatum, Potamogeton crispus, Typha angustifolia*

Table 5. Wolf Lake Aquatic Plant Species, 2005

Scientific Name	Common Name	I. D. Code
Emergent Species		
1) *Calamagrostis canadensis* (Michx.) P.Beauv.	bluejoint grass	calca
2) *Carex* spp.	sedge	carsp
3) *Eleocharis smallii* Britt.	creeping spikerush	elesm
4) *Scirpus validus* Vahl.	softstem bulrush	sciva
5) *Typha angustifolia* L.	narrow-leaf cattail	typan
6) *Typha latifolia* L.	common cattail	typla
Floating-leaf Species		
7) *Nymphaea odorata* Aiton.	white water lily	nymod
8) *Polygonum amphibium* L.	water smartweed	polam
Submergent Species		
9) *Ceratophyllum demersum* L.	coontail	cerde
10) *Chara* sp.	muskgrass	chasp
11) *Eleocharis acicularis* (L.) R & S.	needle spikerush	eleac
12) *Elodea canadensis* Michx.	common waterweed	eloca
13) *Myriophyllum heterophyllum* Michx.	variable-leaf water-milfoil	myrhe
14) *Myriophyllum sibiricum* Komarov.	common water milfoil	myrsi
15) *Myriophyllum spicatum* L.	Eurasian water milfoil	myrsp
16) *Najas guadalupensis* (Spreng.) magnus.	common water-nymph	najgu
17) *Nitella* sp.	nitella	nitsp
18) *Potamogeton amplifolius* Tuckerman.	large-leaf pondweed	potam
19) *Potamogeton crispus* L.	curly-leaf pondweed	potcr
20) *Potamogeton foliosus* Raf.	leafy pondweed	potfo
21) *Potamogeton gramineus* L.	variable-leaf pondweed	potgr
22) *Potamogeton illinoensis* Morong.	Illinois pondweed	potil
23) *Potamogeton natans* L.	floating-leaf pondweed	potna
24) *Potamogeton pectinatus* L.	sago pondweed	potpe
25) *Potamogeton pusillus* L.	small pondweed	potpu
26) *Potamogeton praelongus* Wulf.	white-stem pondweed	potpr
27) *Potamogeton richardsonii* (Ar. Benn.) Rydb.	clasping-leaf pondweed	potri
28) *Potamogeton robbinsii* Oakes.	fern-leaf pondweed	potro
29) *Potamogeton zosteriformis* Fern.	flatstem pondweed	potzo
30) *Ranunculus longirostris* Godron.	white watercrowfoot	ranlo
31) *Sagittaria* spp.	arrowhead rossettes	sagsp
32) *Zosterella dubia* (Jacq.) Small	water stargrass	zosdu

FREQUENCY OF OCCURRENCE

Elodea canadensis was the most frequently occurring species in Wolf Lake in 2005, (83% of sample sites) (Figure 5). *Ceratophyllum demersum, Chara* spp.*, Myriophyllum spicatum, Najas guadalupensis, Nymphaea odorata, Potamogeton pectinatus, P. richardsonii* and *Sagittaria* spp. were also commonly occurring species, (29%, 75%, 27%, 69%, 25%, 31%, 25%, 21% respectively).

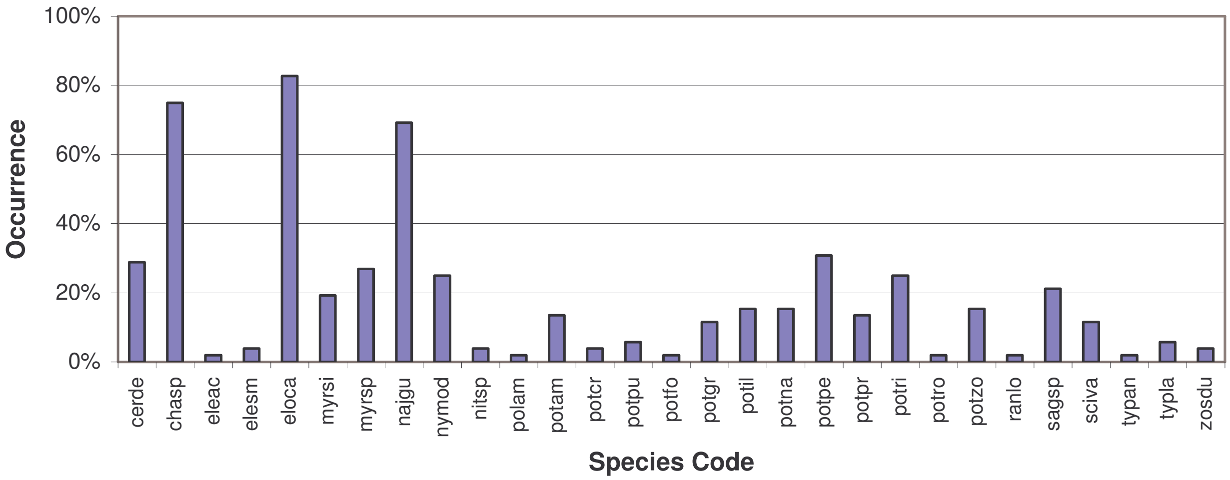


Figure 5. Frequency of occurrence of aquatic plant species in Wolf Lake, 2005.

DENSITY

Chara spp. was the species with the highest mean density in Wolf Lake (2.15 on a density scale of 0-4) (Figure 6). *Elodea canadensis* and *Najas guadalupensis* had mean densities nearly as high (2.00 and 1.92).

Chara spp. had a "mean density where present" of 2.87 (Appendix II). The "mean density where present" indicates that, where *Chara* occurred, it exhibited a growth form of above average density in Wolf Lake. *Najas guadalupensis, Scirpus validus* and *Typha angustifolia* also had "densities where present" of 2.5 or more, indicating that they also exhibited an aggregated growth form or a growth form of above average density (Appendix II). However, *S. validus* and *T. angustifolia* were not commonly occurring in Wolf Lake.

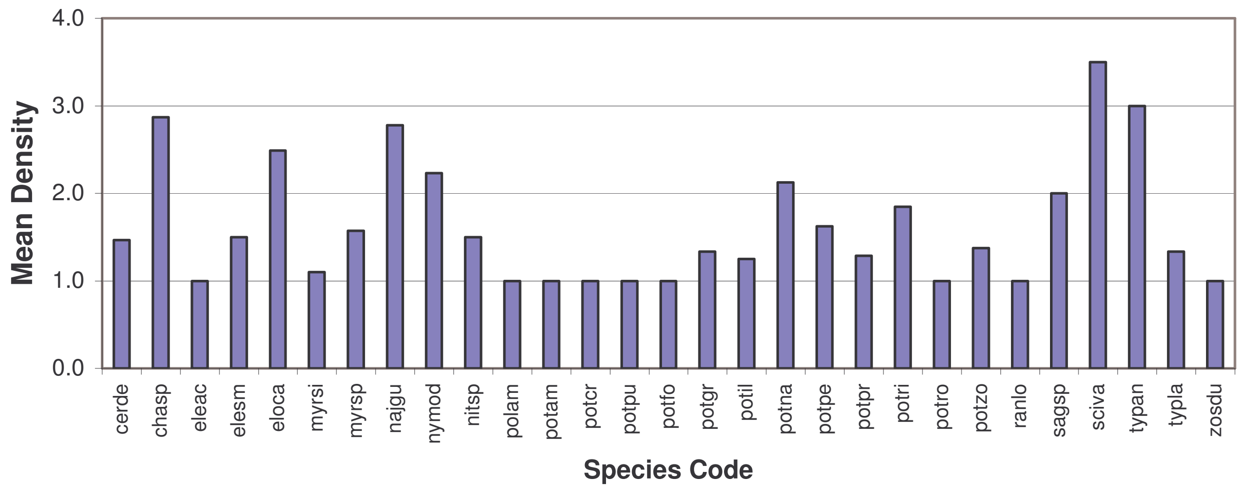


Figure 6. Mean density of aquatic plant species in Wolf Lake, July 2005.

DOMINANCE

Combining the relative frequency and relative density of a species into a Dominance Value illustrates how dominant that species is within the aquatic plant community (Appendix III). Based on the Dominance Value, *Chara* spp. and *Elodea canadensis* were co-dominant aquatic plant species in Wolf Lake (Figure 7). *Najas guadalupensis* was sub-dominant.

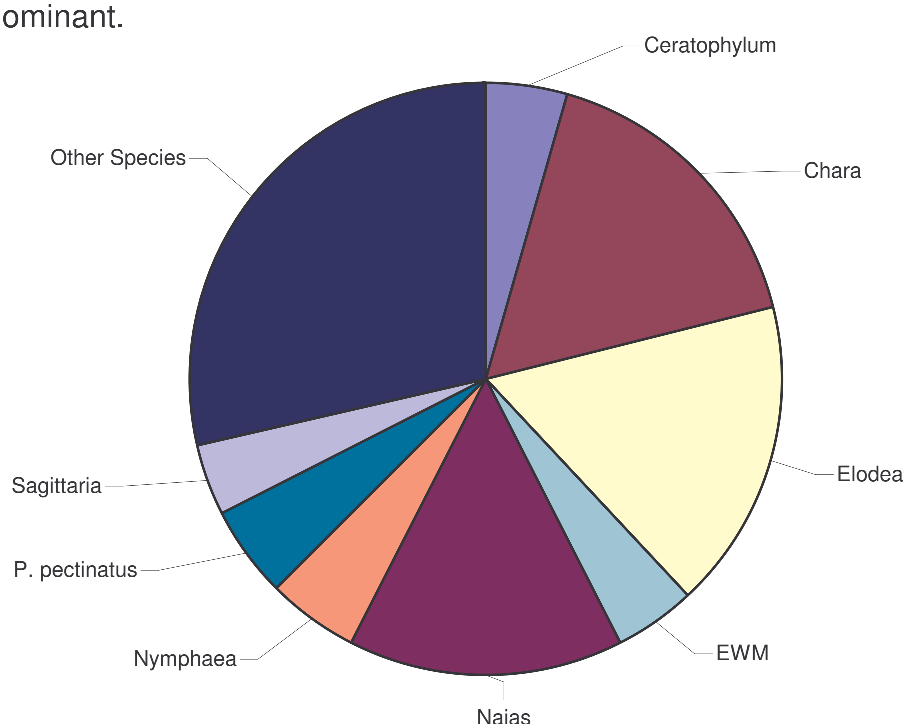


Figure 7. Dominance within the aquatic plant community, of the most prevalent plants in Wolf Lake, 2005.

Chara spp., a co-dominant species overall, was the dominant species in the 0-5 ft depth zone. *Chara* occurred at its highest frequency and density in the 1.5-5ft depth zone (Figure 8, 9). *Elodea canadensis*, the other co-dominant species overall, was the dominant species in the 10-20ft depth zone and the species with the highest frequency in the 5-10ft depth zone. *E. canadensis* occurred at its highest frequency and density in the 10-20ft depth zone (Figure 8, 9).

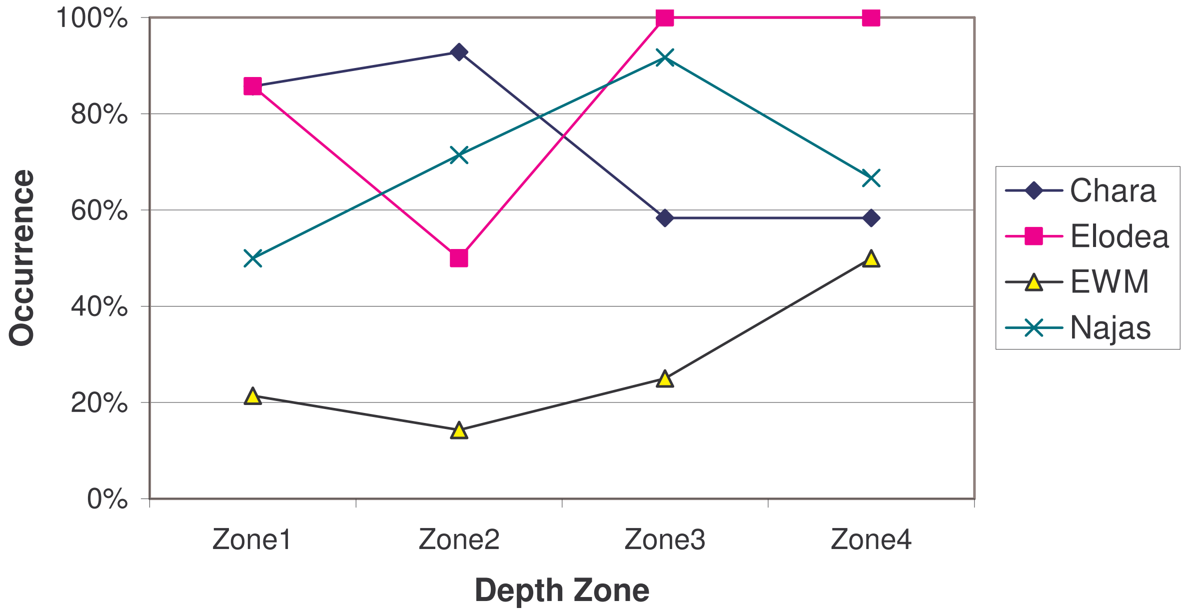


Figure 8. Frequency of occurrence of prevalent aquatic plant species in Wolf Lake, by depth zone, 2005.

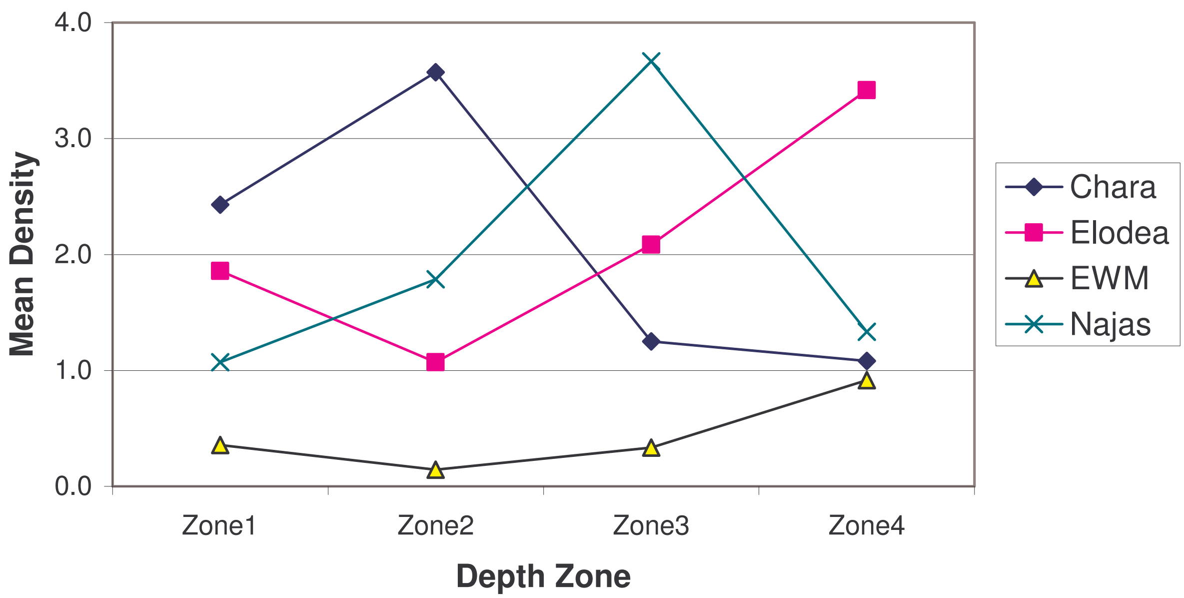


Figure 9. Density of prevalent plant species in Wolf Lake by depth zone, 2005.

DISTRIBUTION

Aquatic plants occurred throughout the entire littoral zone of Wolf Lake, at all of the sampling sites to a maximum depth of 17.5 feet (Figure 10). Approximately 26 acres of the entire lake (53%) was vegetated. Of these 26 acres, about 6 acres (13% of the lake) supported floating-leaf vegetation and about 4 acres (8% of the lake) support emergent vegetation. *Elodea canadensis* and *Myriophyllum spicatum* occurred at the maximum rooting depth.

The dominant and common plant species were found throughout the lake. The exception was *Myriophyllum spicatum*, which did not occur along the north shore. *M. spicatum*, the non-native species, colonized approximately 8 acres (17% of the lake surface) in July 2005 (Figure 11). *M. spicatum* was a commonly occurring species in Wolf Lake, but was abundant only at depths greater than 10 feet. It occurred at below average density throughout the lake and ranked as 6th (with two other species) in lakewide abundance (Appendix I-III).

Secchi disc water clarity data can be used to calculate a predicted maximum rooting depth for plants in a lake (Dunst 1982).

Predicted Rooting Depth (ft.) = (Secchi Disc (ft.) * 1.22) + 2.73

Based on the 2005 Secchi disc clarity, the predicted maximum rooting depth in Wolf Lake would be 24.5 ft.

The actual maximum rooting depth is much less than the predicted maximum rooting depth based on water clarity for 2005 (Figure 12). However, the water clarity in 2004 and 2005 was much better than previous years. The actual maximum rooting depth (17.5 feet) is close to the predicted rooting depth based on clarity during 2002-03. When water clarity increases, it may take a few years for aquatic plants to spread to deeper waters in order to take advantage of better clarity.

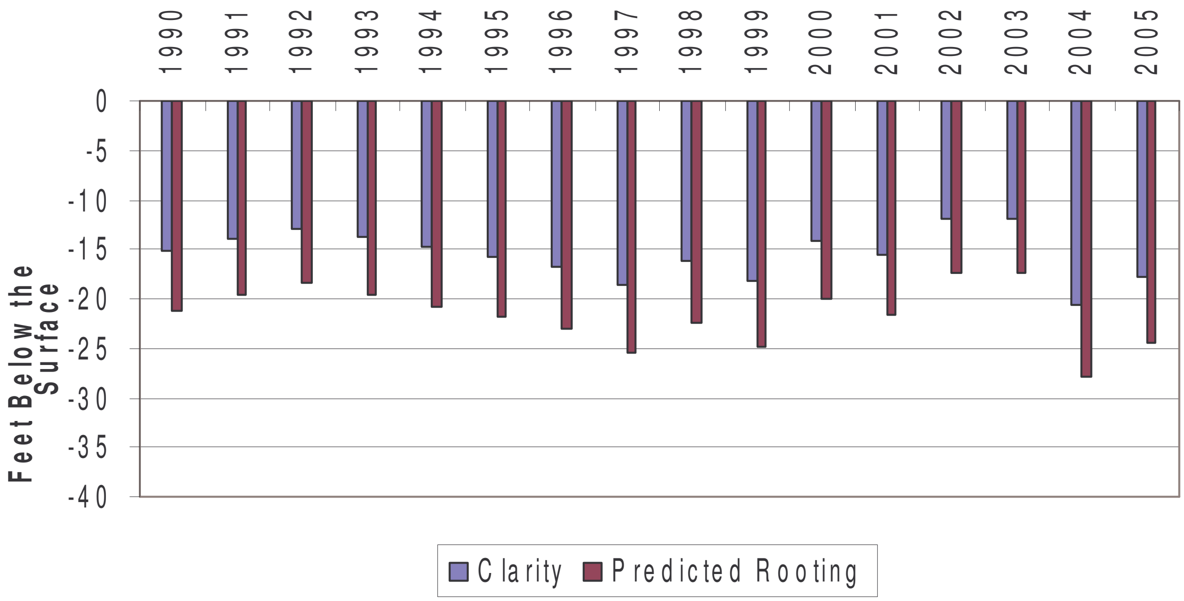


Figure 12. Predicted maximum rooting depth based on water clarity, 1990-2005.

The 0-1.5ft depth zone supported the greatest amount of plant growth. The highest total occurrence and total density of plant growth was recorded in the 0-1.5ft depth zone (Figure 13).

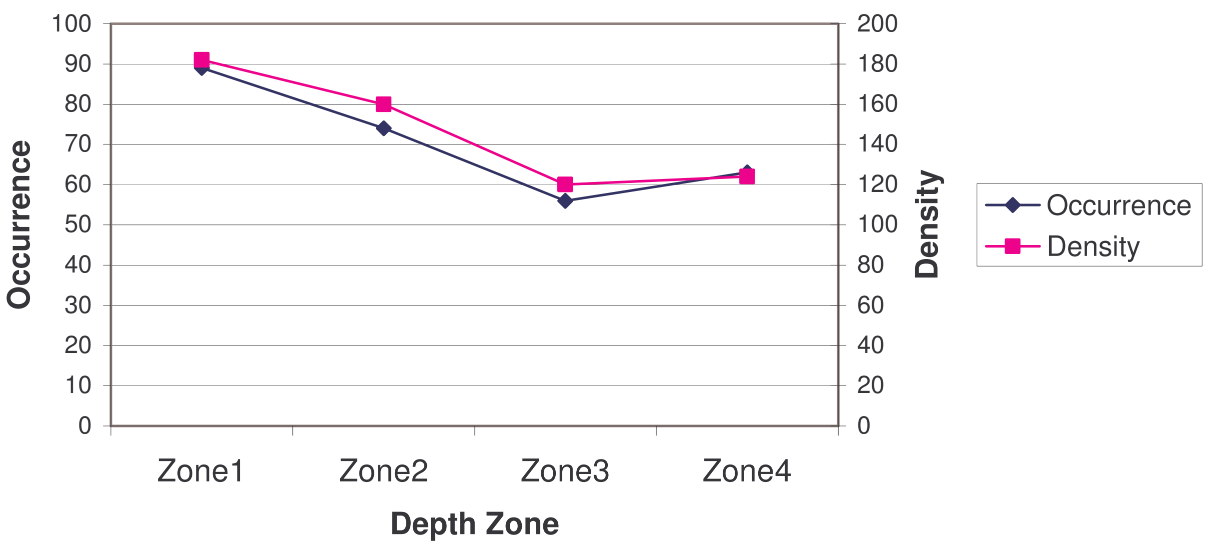


Figure 13. Total occurrence and total density of plants in Wolf Lake by depth zone.

The greatest species richness (mean number of species per site) was also recorded in the 0-1.5 ft. depth zone (Figure 14). Overall species richness in Wolf Lake was 5.4 species per site.

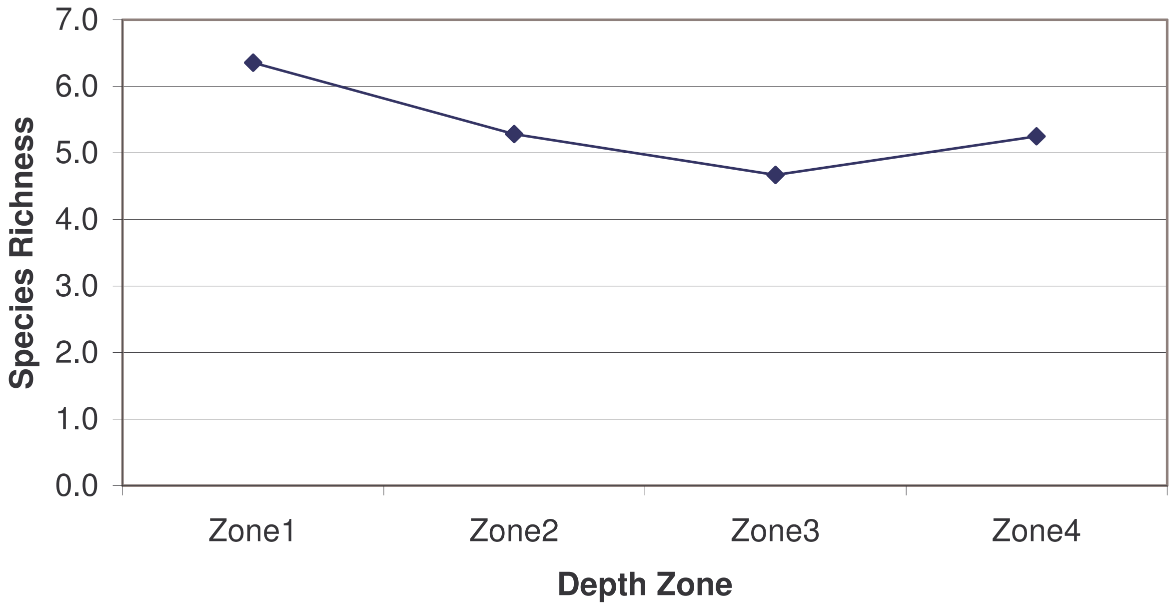


Figure 14. Species richness in Wolf Lake, by depth zone, 2005.

THE COMMUNITY

Simpson's Diversity Index was 0.92, indicating excellent species diversity. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable). The Aquatic Macrophyte Community Index (AMCI) for Wolf Lake (Table 6) is 61. This is in the upper quartile of lakes in Wisconsin and the North Central Hardwoods Region of the state. This value places Wolf Lake in the top 25% of lakes in the state and region with the highest quality aquatic plant communities.

Table 6. Aquatic Macrophyte Community Index, Wolf Lake 2005

Category		Value
Maximum Rooting Depth	5.3 meters	10
% Littoral Zone Vegetated	100%	10
% Submergent Species	81% Relative Freq.	10
# of Species	31	10
% Exotic Species	6%	5
Simpson's Diversity Index	0.92	10
% Sensitive Species	10% Relative Freq.	6
Totals		61

* The highest value for this index is 70

The Average Coefficient of Conservatism for Wolf Lake was below average for Wisconsin lakes and lakes in the North Central Hardwood Region (Table 7). This suggests that the aquatic plant community in Wolf Lake is less sensitive to disturbance than the average lake in the state or region. This is likely due to selection of species by past disturbance.

Table 7. Floristic Quality and Coefficient of Conservatism of Wolf Lake, Compared to Wisconsin Lakes and Northern Wisconsin Lakes.

	Average Coefficient of Conservatism †	Floristic Quality ‡	
			Based on Relative Frequency
Wisconsin Lakes	5.5, 6.0, 6.9 *	16.9, 22.2, 27.5	
NCHR	5.2, 5.6, 5.8 *	17.0, 20.9, 24.4	
Wolf Lake 2005	5.50	29.10	25.71

* - Values indicate the highest value of the lowest quartile, the mean and the lowest value of the upper quartile.

† - Average Coefficient of Conservatism for all Wisconsin lakes ranged from a low of 2.0 (the most disturbance tolerant) to a high of 9.5 (least disturbance tolerant).

‡ - lowest Floristic Quality was 3.0 (farthest from an undisturbed condition) and the high was 44.6 (closest to an undisturbed condition).

The Floristic Quality Index of the aquatic plant community in Wolf Lake was in the upper quartile of Wisconsin lakes and North Central Hardwood Region lakes (Table 7). This indicates that the plant community in Wolf Lake is within the group of lakes in the state and region closest to an undisturbed condition.

However, this calculation was based only on the presence or absence of sensitive and tolerant species; their occurrence or dominance in the community was not taken into consideration. The Floristic Quality Index was recalculated, weighting each species coefficient with its relative frequency in the community. The resulting index was slightly different. The FQI was still in the upper quartile of lakes in the North Central Hardwood Region, but was above average when compared to lakes in the entire state. This suggests that Wolf Lake is in the upper quartile of lakes in the North Central Hardwood Region, the group of lakes closest to an undisturbed condition. When compared to all Wisconsin Lakes, Wolf Lake is closer to an undisturbed condition than the average lake in the state.

Disturbances can be of many types:

1) Physical disturbances to the plant beds result from activities such as boat traffic, plant harvesting, chemical treatments, the placement of docks and other structures and fluctuating water levels.
2) Indirect disturbances are the result of factors that impact water clarity and thus stress species that are more sensitive: resuspension of sediments, sedimentation from erosion and increased algae growth due to nutrient inputs.
3) Biological disturbances include competition from the introduction of a non-native or invasive plant species, grazing from an increased population of aquatic herbivores and destruction of plant beds by a fish or wildlife population.

The major disturbances in Wolf Lake are likely:
1) the introduction of non-native aquatic plant species and the subsequent chemical treatments
2) shoreline development
3)

IV. DISCUSSION

Based on water clarity, chlorophyll and phosphorus data, Wolf Lake is an oligotrophic lake with excellent water clarity and very good water quality. The relatively small watershed helps retain the water quality in Wolf Lake. Trend analysis shows that algae and nutrients have increased during 1997-2004. The current trophic state should support sparse plant growth and infrequent algae blooms. Filamentous algae occurred at 31% of the sites, common in the 0-5ft depth zone and abundant in the 5-10ft depth zone. Adequate nutrients, the excellent water clarity and the moderate-to-gradually sloped littoral zone in Wolf Lake would favor plant growth.

Aquatic plants occurred throughout the entire littoral zone, 53% of the lake surface (26 acres), to a maximum depth of 17.5 feet. The highest total occurrence of plants, highest total density of plants and the greatest species richness occurred in the 0-1.5ft depth zone. Overall species richness was 5.4.

Thirty-two (32) species of aquatic plants were recorded in Wolf Lake in 2005. *Chara* spp. and *Elodea canadensis* were co-dominant plant species in Wolf Lake.

- *Elodea canadensis* was the species with the highest frequency in Wolf Lake, colonizing more than three-quarters of the littoral zone, dominant in the 10-20ft depth zone and occurring with Eurasian watermilfoil at the maximum rooting depth.
- *Chara* spp. was the species with the highest mean density in Wolf Lake, exhibiting a growth form of above average density and dominant in the 0-5ft depth zone.
- *Najas guadalupenis* was sub-dominant, exhibiting a growth form of above average density.

Seven (7) other species were commonly occurring. Two (2) other species exhibited an aggregated or dense growth form in Wolf Lake, but were not commonly occurring in Wolf Lake. The dominant and common species, except Eurasian watermilfoil, were found throughout the lake.

Eurasian watermilfoil has been introduced in Wolf Lake, but since lake-wide treatments (targeting milfoil wherever it is found in the lake) began in 2002, the acreage of milfoil treatments has declined from 9.5 to 5 acres. In July 2005, Eurasian watermilfoil was a commonly occurring species, but occurred at below average densities, and was abundant only at depths greater than 10 feet, occurring at the maximum rooting depth with *Elodea canadensis*. It was not found along the north shore. Its recurrence in the deeper areas and coverage of approximately 8-acres by July is likely due to the problem of decreasing chemical effectiveness with deeper water.

The Aquatic Macrophyte Community Index (AMCI) for Wolf Lake was 61, indicating that the quality of the plant community in Wolf Lake is high, in the top quartile of lakes in Wisconsin and the region. Simpson's Diversity Index (0.92) indicates that the aquatic plant community had an excellent diversity of plant species.

The Average Coefficient of Conservatism and the Floristic Quality Index indicate that Wolf Lake has a below average sensitivity to disturbance and is in the upper quartile of lakes (top 25%) in the North Central Hardwood Region, the group of lakes in the region closest to an undisturbed condition. When compared to lakes over the whole state, Wolf Lake was above average, closer to an undisturbed condition than the average lake.

Shoreline Impacts

Wolf Lake has some protection with abundant natural shoreline cover (wooded, shrub, native herbaceous growth), but disturbed shoreline covered 35% of the shore. Two types of disturbed cover, cultivated lawn and hard structures, were commonly occurring. Cultivated lawn covered 30% of the shoreline.

Shorelines with cultivated lawn can impact the plant community through increased run-off of lawn fertilizers, pesticides and pet wastes into the lake. Hard structures and mowed lawn also speed run-off to the lake without filtering these pollutants. Expanding and protecting the buffer of natural vegetation along the shore will help prevent shoreline erosion and reduce additional nutrient/chemical run-off that can add to algae growth and sedimentation of the lake bottom.

To measure the impact of shoreline disturbance, the aquatic plant transects at sites with 100% natural shoreline were compared to aquatic plant transect sites at shoreline that contained any amount disturbance (Appendices V-VIII). The comparison of various parameters indicate that disturbance on the shore has impacted the aquatic plant community at those sites.

The Average Coefficient of Conservatism was higher at the natural shoreline communities (Table 8). This indicates that the plant community at disturbed shoreline is more tolerant of disturbance, likely from being subjected to disturbance.

Filamentous algae had a much higher occurrence at sites at disturbed shoreline as compared to natural shoreline. This suggests nutrient enrichment is occurring at disturbed shoreline sites (Table 8). Nutrient sources could be lawn fertilizers, failing or poorly maintained septic systems, pet wastes and poorer filtering capacity of hard surfaces and mowed lawns.

Eurasian watermilfoil, an non-native, invasive plant species, also had a much higher occurrence and mean density at disturbed shoreline sites (Table 8). In addition, its "density were present" was higher at disturbed shoreline sites, indicating that Eurasian milfoil exhibited a denser growth form at disturbed sites. Two other non-native, exotic species (curly-leaf pondweed and narrow-leaf cattail) occurred only at disturbed shoreline sites. Disturbance creates an ideal condition for exotic species to colonize and spread.

Conversely, the most sensitive species in Wolf Lake (Nichols 2000) occurred at a much higher frequency, grew at a higher density and had a higher dominance at the sites near natural shoreline (Table 8). This corroborates the impact disturbed shoreline has on the aquatic plant community.

Table 8. Comparison of the Aquatic Plant Community at Natural Shoreline Sites and Disturbed Shoreline Sites.

Parameter		**Natural Shoreline**	**Disturbed Shoreline**
Average Coefficient of Conservatism		5.72	5.50
Eurasian watermilfoil (EWM)	Frequency	6%	36%
	Mean Density	0.06	0.58
	Density where present	1.00	1.62
Other Exotic Species	Curly-leaf pondweed	0	6%
	Narrow-leaf cattail	0	3%
Most Sensitive Species: *Potamogeton praelongus*	Overall Dominance	0.10	0.02
	Frequency	25%	8%
	Mean Density	0.38	0.08
Filamentous Algae	Percent Occurrence	19%	36%

Changes in the Aquatic Plant Community, 1948-2005

Studies conducted in 1948 were qualitative, and studies conducted in 2002-04 were quantitative using different transect locations and different times during the growing season, so that direct comparisons can not be made. However, (added comma) some inferences can be drawn.

Three species that were recorded in 1948 were not found. *Potamogeton nodosus* and *Scirpus americanus* have not been recorded since 1948, and *Vallisneria americana* has not been recorded since 2002.

Two species recorded during the 2002/04 surveys were not recorded in 2005: *Brasenia schreberi* and *Potamogeton epihydrus.*

Many differences between the 2002/04 and 2005 surveys can be attributed to the difference in timing during the growing season (Table 9) since aquatic plants reach their full growth in Mid-June to July. After the 2002 and 2003 treatment for Eurasian watermilfoil, the only species that showed significant changes (Cason and Roost 2004) were significant increases in *Elodea canadensis, Potamogeton crispus, P. illinoensis, P. zosteriformis* and a significant decrease in *Myriophyllum spicatum* (Table 9). The decrease in *M. spicatum* was expected since the treatments were conducted to control this species. The increase in the other species are likely due to these species spreading and colonizing areas previously colonized by *M. spicatum. Potamogetons* spp. and *Elodea* are not impacted by the chemical used for *M. spicatum.* There have been significant, but temporary, increases of *Elodea* on other lakes in the area after chemical watermilfoil treatments.

Table 9. Change in Aquatic Plant Species in Wolf Lake, 1948-2005.

Scientific Name	1948*	May2002^	May2004^	July 2005
Emergent Species				
1) *Calamagrostis canadensis*				
2) *Carex* spp.				
3) *Eleocharis smallii*				
4) *Scirpus validus*	Common	Scattered		Scattered
5) *Typha angustifolia*				
6) *Typha latifolia*				
Floating-leaf Species				
7) *Nymphaea odorata*	Common	Scattered	Scattered	Common
8) *Polygonum amphibium*				
Submergent Species				
9) *Ceratophyllum demersum*	Abundant	Scattered	Scattered	Common
10) *Chara* sp.	Scattered	Common	Abundant	Dominant
11) *Eleocharis acicularis*				
12) *Elodea canadensis*	Common	Scattered	Abundant	Dominant

13) *Myriophyllum heterophyllum*				
14) *Myriophyllum sibiricum*	Scattered	Scattered	Scattered	Common
15) *Myriophyllum spicatum*		Dominant		Common
16) *Najas guadalupensis*		Scattered	Scattered	Abundant
17) *Nitella* sp.		Scattered		Scattered
18) *Potamogeton amplifolius*		Scattered	Scattered	Scattered
19) *Potamogeton crispus*		Scattered	Common	Scattered
20) *Potamogeton foliosus*.				
21) *Potamogeton gramineus*				
22) *Potamogeton illinoensis*		Scattered	Common	Scattered
23) *Potamogeton natans*			Scattered	Scattered
24) *Potamogeton pectinatus*	Scattered			
25) *Potamogeton pusillus*				
26) *Potamogeton praelongus*	Abundant	Scattered		Scattered
27) *Potamogeton richardsonii*			Scattered	Common
28) *Potamogeton robbinsii*				
29) *Potamogeton zosteriformis*	Scattered	Scattered	Scattered	Scattered
30) *Ranunculus longirostris*	Scattered			
31) *Sagittaria* spp.				
32) *Zosterella dubia*	Scattered		Scattered	Scattered

* - Ironside, 1948
^ - Cason and Roost 2004

V. CONCLUSIONS

Wolf Lake is an oligotrophic lake with very good water quality and excellent water clarity. Nutrients and algae have increased since 1997. Filamentous algae is common in Wolf Lake, abundant in the 5-10ft depth zone.

The aquatic plant community colonized approximately half of Wolf Lake, 100% of the littoral zone to a maximum rooting depth of 17.5 feet. The 0-1.5ft depth zone supported the most abundant aquatic plant growth.

Chara spp. and *Elodea canadensis* were the co-dominant species within the 32-species aquatic plant community. *Chara* was codominant especially in the 0-5' depth zone, while *Elodea Canadensis* was more codominant in the 10'-20' depth zone. *Najas guadalupensis* was sub-dominant. The most common species (except Eurasian watermilfoil) were found distributed throughout the lake.

Eurasian watermilfoil has been introduced in Wolf Lake, but since lake-wide treatments for the milfoil began in 2002, the acreage of treatment has declined from 9.5 to 5 acres. In July 2005, Eurasian watermilfoil was a commonly occurring species, but occurred at below average densities and was abundant only at depths greater than 10 feet, occurring at the maximum rooting depth with *Elodea canadensis*.

The Wolf Lake aquatic plant community is characterized by high quality and excellent species diversity. The plant community has a below average sensitivity to disturbance and is closer to an undisturbed condition than the average lake in the state. In the

North Central Hardwoods Region, Wolf Lake is in the top quartile of lakes, the group of lakes closest to an undisturbed condition.

A healthy aquatic plant community plays a vital role within the lake community. This is due to the role plants play in

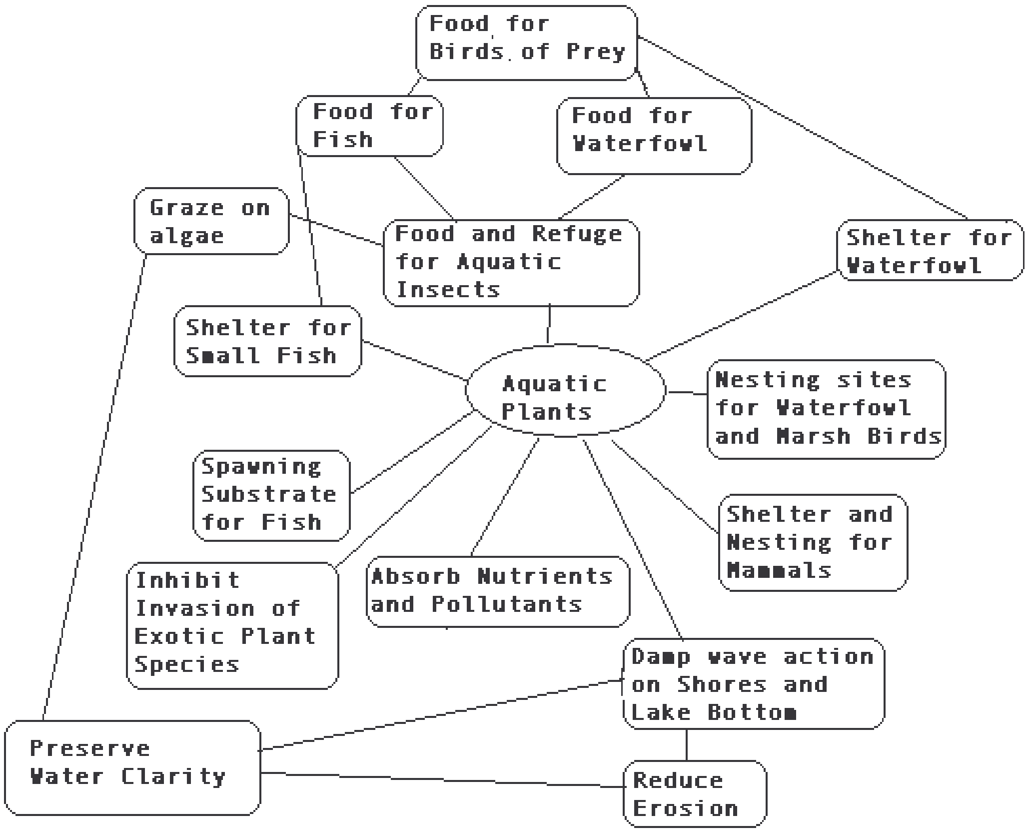
1) improving water quality 2) providing valuable habitat resources for fish and wildlife 3) resisting invasions of non-native species and 4) checking excessive growth of tolerant species that could crowd out the more sensitive species, thus reducing diversity.

Aquatic plant communities improve water quality in many ways (Engel 1985):

- they trap nutrients, debris, and pollutants entering a water body;
- they absorb and break down some pollutants;
- they reduce erosion by damping wave action and stabilizing shorelines and lake bottoms;
- they remove nutrients that would otherwise be available for algae blooms.

Aquatic plant communities provide important fishery and wildlife resources. Plants and algae start the food chain that supports many levels of wildlife, and at the same time produce oxygen needed by animals. Plants are used as food, cover and nesting/spawning sites by a variety of wildlife and fish (Table 10). Plant cover within the littoral zone of Wolf Lake is 100% and over the whole lake is 53% and is appropriate (25-85%) to support a balanced fishery.

Compared to non-vegetated lake bottoms, plant beds support larger, more diverse invertebrate populations that in turn will support larger and more diverse fish and wildlife populations (Engel 1985). Additionally, mixed stands of aquatic plants support 3 to 8 times as many invertebrates and fish as monocultural stands (Engel 1990). Diversity in the plant community creates more microhabitats for the preferences of more species. Aquatic plant beds of moderate density support adequate numbers of small fish without restricting the movement of predatory fish (Engel 1990).



Management Recommendations

(1) All lake residents should practice best management on their lake properties. including. Increases in nutrients and algae since 1997 and higher filamentous algae occurrence at developed shoreline may be an early warning that nutrient enrichment is impacting the lake and is coming from developed shoreline. The watershed of Wolf Lake is relatively small and would not likely contribute significant nutrients. Such practices include:

a) Keep septic systems cleaned and in proper condition
b) Use no lawn fertilizers
c) Clean up pet wastes
d) near the water or allow yard wastes and clippings to enter the lake

(2) Residents should continue involvement in the Self-Help Volunteer Lake Monitoring Program, monitoring water quality to track seasonal and year-to-year changes.

(3) Adams County should designate sensitive areas within Wolf Lake. These are areas within the lake that are most important for habitat and maintaining water quality.

(4) Lake residents should protect natural shoreline around Wolf Lake. Wolf Lake has

protection from natural shoreline buffers on large areas of the lake, but disturbed shoreline (cultivated lawn and hard structures) is abundant, covering more than one-third of the shore. Cultivated lawn alone covers 30% of the shore. Unmowed native vegetation reduces shoreline erosion and run-off into the lake plus filters the run-off that does enter the lake. Comparison of the plant communities at natural shoreline and disturbed shoreline suggest shoreline disturbance is already impacting the aquatic plant community. Evidence that disturbance on shore is impacting the plant community in the water is that the disturbed shoreline plant species assemblage is more tolerant of disturbance and disturbed shoreline sites in Wolf Lake support lower frequency and density of the most sensitive species.

Disturbed shoreline sites support an aquatic plant community that is less able to resist invasions of exotic species. Eurasian watermilfoil occurred at higher frequencies and densities at disturbed shoreline sites. The two other exotic species occurred only at disturbed shoreline sites. Filamentous algae occurred at a much higher percentage of sites at disturbed shoreline as compared to natural shoreline.

(5) All lake users should protect the aquatic plant community in Wolf Lake. The standing-water emergent community, floating-leaf community and submergent plant community are all unique plant communities. Each of these plant communities provides their own benefits for fish and wildlife habitat and water quality protection.

(6) The Wolf Lake Association should maintain exotic species signs at the boat landings to educate lake users. The DNR should be contacted if the signs are missing or damaged.

(7) The Wolf Lake Association should continue monitoring and control of Eurasian watermilfoil. It appears to be declining at present. Monitoring colonization of the milfoil will help association determine if the control methods remain effective or if they need to be modified.

a. Continue early-season treatments with a specific chemical as long as it remains effective
b. Investigate ways to increase treatment effectiveness in the deeper water
c. Residents may need to hand pull scattered plants as chemical is less effective on these scattered individuals

(8) Lake Association should contract with a University or the County to have a milfoil weevil survey conducted to determine if this natural method of control could be a feasible and steps could be made to increase the weevil population.